

AMMENDMENTS TO THE SPECIFICATION

1. Pursuant to 37 C.F.R. § 1.121(b), this separate paper is submitted showing amendments to the Specification.

2. Please replace the paragraph in the Specification at 2:3-45 beginning "RSW is the most widely used . . ." and ending "higher cost operations." as follows:

RSW is the most widely used joining method for thin sheet metals, particularly in the automotive industry. There is, particularly in the automotive industry, growing interest in the use of aluminum and aluminum alloys in automobile structures. (It is to be understood herein that any reference to aluminum, unless otherwise indicated, refers also to aluminum alloys.) It is recognized, further, that RSW is a key technology in the volume production of aluminum sheet structures. While conventional RSW is quite satisfactory for joining, for example, steels, other metals, particularly aluminum, present unique problems. First, aluminum has a high chemical affinity for oxygen and, therefore, forms a film of oxide when exposed to air. This oxide film not only presents a barrier of high electrical resistance which must be overcome to supply current to the workpiece, it also exhibits high heat transfer which conducts heat away from the workpiece so quickly that a nugget may not form properly. In addition, the oxide layer has a high melting point – an important consideration also at the interface between the two sheets. These attributes result in the need for higher current densities and associated higher electrode temperatures to produce a satisfactory weld. Second, aluminum itself has high thermal and electrical conductivities as well as a high heat of fusion. To overcome these properties and generate enough heat at the weldsite to create a satisfactory nugget, a higher welding current is required in a relatively shorter period of time. Finally, aluminum has a narrower plastic temperature range and a larger thermal expansion coefficient. These properties necessitate a high electrode force in order to avoid inner stress-induced cracking during the nugget formation process. In addition, the required electrode force for aluminum, relative to surface hardness, is much higher than, for example, steel. However, since contact resistance is inversely proportional to electrode force, a higher current density is required to create the necessary heat to form a satisfactory nugget when a higher electrode force is used. The force is generally of such a

magnitude that, along with the increased temperature of the electrode due to high current densities, a mushrooming ~~effect~~ effect is observed around the periphery of the electrode tip. The combination of these properties imposes a severe working environment of high mechanical and thermal stresses upon the electrodes. The electrodes ~~are~~ run hotter and, at the same time, are subjected to higher forces. This, in turn, results in shorter electrode life, reduced productivity, and higher cost operations.

3. Please replace the paragraph in the Specification at 12:11-17 beginning “During the operation, the pair . . .” and ending “a solid nugget 120.” as follows:

During operation, the pair of electrodes 110 ~~are~~ is arranged in a facing, spaced-apart relationship, a workpiece 122, comprising two pieces of sheet metal 124 is interposed between the electrodes 110, the workpiece 122 is then squeezed between the electrodes 110 with a specified force, and a current of specified amperage is applied for a specified number of electrical cycles. The current flow causes the temperature of the faying surface 132 between the two pieces of sheet metal 124 to rise causing the metal to melt and, when fused, to form a solid nugget 120.

4. Please replace the paragraph in the Specification at 12:18-13:13 beginning “Turning next to Figs 1b-1f . . .” and ending “the nugget 120 is 3.1 mm.” as follows:

Turning next to Figs 1b-1f, the conditions during operation for the configuration of Fig. 1a are illustrated. In all FEA examples shown herein, the conditions shown in Table 2 below were used unless otherwise specified.

Table 2

| <u>Parameter</u> | <u>Value</u> |
|--------------------------------|--------------|
| Base Metal Type | 5XXX Al |
| Base Metal Thickness (mm) | 2 |
| Total Workpiece Thickness (mm) | 4 |
| Electrode Material | Cu |
| Current (KA) | 22 |

| | |
|-----------------------|------|
| Force (pounds-force) | 1550 |
| Weld Time (cycles) | 10 |
| Squeeze Time (cycles) | 60 |

Fig. 1b shows the current density profile throughout the electrodes 110 and the workpiece 122. The current density profile shows that the current is distributed over the entire interface between the electrode face 121 and the workpiece 122. In addition, the current is concentrated near the faying surface 132. Similarly, Fig. 1c shows the temperature profile. The highest temperature range 111A is between 590-603 deg. C and indicates the formation of a nugget 120. In this example, however, the nugget 120 is too small to be effective. For a nugget 120 to be effective, it must have a vertical coverage, the percent of the thickness of the nugget 120 to the total thickness of the workpiece 122 of between 20 and 80 percent and preferably about 40 percent and have a diameter as large as possible. For example, if the nugget 120 is too thin, the weld will have insufficient strength, if the nugget 120 is too thick, however, the high temperature can cause the electrode 110 to become overheated. The nugget 120 in the example shown in Figs 1a and 1c, however, is only 0.96 mm thick, or 24 percent of the total 4 mm thickness of the workpiece 122. This dimension is acceptable, but at the lower end of the desired range and well below the preferred value of 40 percent. The diameter of the nugget 120 is 3.1 mm.

5. Please replace the paragraph in the Specification at 15:1-16:10 beginning "Turning now to an embodiment . . ." and ending "of the coolant channel 414." as follows:

Turning now to an embodiment of the present invention, Fig. 4a shows a pair of electrodes 410 comprising first a shank portion 412, which, for purposes of comparison, has a diameter of 16 mm, but which can vary from 8-24 mm depending upon the application, which is formed to include a coolant channel 414 having a diameter of 9 mm. The coolant channel 414 diameter may vary depending upon the diameter of the shank 412. In addition, the coolant channel 414 shape may vary depending upon the application. Second is a tapered section 416, adjacent to, and integral with, the shank portion 412. Again, for purposes of comparison, the tapered portion 416 has a height in the axial direction of 3 mm and an angle relative to the radius of 45 degrees, but which can vary from 0 mm (no tapered section 416) to about 8 mm and have an angle of 30-90 degrees relative to the radius depending upon the application. Third is a tip portion 418,

adjacent to, and integral with, the tapered portion 416. Again, for purposes of comparison, the tip portion 418 has a height in the axial direction of 2.4 mm and a diameter of 10 mm. For consistency and comparison purposes, the tip portion 418 is formed to include a flat face 421. Each electrode 410 also comprises first an annular sleeve 440 having a thickness in the radial direction between 0.5-2.5 mm, preferably between 0.5-1 mm, and more preferably 0.75 mm, or, more generally, between 10-50 percent of the radius of the tip 418, preferably between 10-20 percent of the radius of the tip 418, and more preferably 15 percent of the radius of the tip 418 and a height in the axial direction between 1-5 mm, preferably between 2-3 mm, and more preferably 2.4 mm, or, more generally, between 20-80 percent of the distance from the face 421 to the bottom of the coolant channel 414, preferably between 40-50 percent of the distance from the face 421 to the bottom of the coolant channel 414, and more preferably 45 percent of the distance from the face 421 to the bottom of the coolant channel 414.[[.]] Second, a co-axial insert 444 having a diameter of 2 mm, preferably between 1-6 mm, more preferably between 3-5 mm, and more preferably 4 mm, or, more generally, between 10-60 percent of the diameter of the tip 418, preferably between 30-50 percent of the diameter of the tip 418, and more preferably 40 percent of the diameter of the tip 418 and a height in the axial direction between 1-5 mm, preferably between 2-3 mm, and more preferably 2.4 mm, or, more generally between 20-80 percent of the distance from the face 421 to the bottom of the coolant channel 414, preferably between 40-50 percent of the distance from the face 421 to the bottom of the coolant channel 414, and more preferably 45 percent of the distance from the face 421 to the bottom of the coolant channel 414. Third, an annular ring 442 having a thickness in the radial direction of between 0.5-3 mm, preferably between 1-3 mm, and more preferably 1.5 mm, or, more generally, between 10-60 percent of the radius of the tip 418, preferably between 20-40 percent of the radius of the tip 418, and more preferably 30 percent of the radius of the tip 418 and a height in the axial direction of between 0.5-2 mm, preferably between 0.75-1.5 mm, and more preferably 1 mm, or more generally, between 10-40 percent of the distance from the tip face 421 to the bottom of the coolant channel 414, preferably between 15-30 percent of the distance from the tip face 421 to the bottom of the coolant channel 414, and more preferably 20 percent of the distance from the tip face 421 to the bottom of the coolant channel 414.